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Determination of the Physicochemical Properties of Tropical Clay Sample when Treated with Granite Sludge

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ABSTRACT
Soft soils such as clay soils, mostly if they comprise swelling minerals may produce great damage to structures, particularly when these soils are exposed to wetting and drying situations. The geotechnical properties of soft soils could be enhanced by utilizing chemical additives. When the clay soil comes in contact with water then excessive swelling is caused and when water content decreases shrinkage occurs in the soil This research work is done in order to determine the strength characteristics of tropical clay treated with granite sludge in order to improve the physicochemical properties of the clay. The analysis done was to check the elemental composition using X-ray fluorescence and the chemical compound using X-ray Diffraction. From the results obtained, the 20 % granite-treated clay sample has the best results chemical composition which will translate to a better strength characteristic. The product of this treatment has been studied in this work to determine its engineering properties and potentials for use in engineering work. However, this modified material can be used as a base material for moderate traffic roads and as a sub-base material for high traffic roads.

Keywords: *Clay, Granite Sludge, X-ray Diffraction, X-ray Redaction.*

1 INTRODUCTION

According to Sani, Bello and Nwadiogbu (2014), the need to reduce the uncertainties in geotechnical engineering during design and construction in terms of the variable nature of soil and rock properties and other in situ conditions has become a major challenge because of the uncertainties in the reliability of design (Afrin, H. 2017) and construction methods, and uncertainties in the costs and benefits of proposed design strategies, when considering clay soil for instance, as a result of its wetting and drying, massive expansion and contraction of the minerals takes place. Contraction leads to the formation of the wide and deep cracks. Cracks measuring 70 mm wide and over 1m deep have been observed (Adeniji, *et al.,* 1991) and may extend up to 3 m or more in the case of high deposit. Surface material accumulates in these cracks during the dry season and is “swallowed” by the soil in the wet season, creating the ‘self-mixing’ or ‘self-mulching’

action of the soils (Al-Kiki *et al*., 2011). These soils are poor materials to employ for highway or airfield construction because they contain high percentages of plastic clay. In areas where they occur, usually there are no suitable natural gravels or aggregates and most deposits cover a large significant area that avoiding them is not possible. Road construction over such soils generally poses a major problem due to the ability of the soils to swell and shrink considerably with changes in moisture content, which consequently lead to low bearing values when wet and severe cracking when dry (Osinubi, 1995).

However, this scenario can be effectively managed when the use of marginal soils is considered (Adejumo *et al.,* 2019). One of the most pressing needs for research in the geotechnical area is on the issue of the use of marginal soils like silts and soft rock for fills and as backfill material for walls and bridge abutments, as one of the key parameters usually considered in soil improvement techniques is strength gain (Adejumo and Olanipekun, 2019)).

Disposal of waste materials generated from different industries causes many problems like environment pollution in the nearby locality, scarcity of land for disposal, etc (Estabragh *et al.,* 2013). Granite dust is a finer material which is obtained during the cutting and polishing process of granite stones in industries. It is produced at the range of 5-6 million tons per annum. It usually looks bright whitish color (Firoozi *et al.,* 2017).

According to Muhunthan and Sariosseiri (2008), additives such as lime, cement, fly ash, lime-cement-fly ash admixture, cement kiln dust, emulsified asphalt, Geofiber, and polymer stabilizers are used to improve their engineering properties. The choice and effectiveness of an additive depends on the type of soil and its field conditions. Nevertheless knowledge of mechanistic behaviour of treated soil is equally important as selecting the stabilizer.

For several decades, attempts have been made towards the preservation and utilization of industrial wastes or waste materials (Vershima, 2014). This is because it is believed that they constitute an important source of alternative raw materials having the same use as its primary raw materials, although they are often referred to as secondary raw materials (El-Maghraby *et al.,* 2011).

In spite of the fact that granite industry in Nigeria generates a large amount of wastes in form of fine grain size powder which during rainy seasons transform into mud leading to some environmental damage, little attention is given to its maximum utilization for other industrial applications apart from its widespread use in the building industry (Eze-Uzoamaka *et al.,* 2010). These necessitate the research in order to utilize granite waste (sludge) for laterite stabilization in road constructions.

2. MATERIALS AND METHODS

2.1 Materials

The soil used in this study was obtained at Minna Metropolis, using the disturbed sampling technique at certain specified depths and was classified according to the AASHTO soil classification systems. This location for sample collection was chosen because it fell in the Nigeria tropical region by the vegetation belts of the country.

The Granite Sludge (GS) was obtained at one of the granite cutting factories located at Yaguru Village, along Abuja-Kaduna express way. This material was sieved to 50 µm and stored in an air-tight container pending when it will be time for sample preparations.

2.2 Sample Preparations

Aggregates of the tropical clay sample collected from the construction site was broken down to smaller particles and be sieve using BS No. 4 sieve (50 µm aperture). Laboratory tests such as the Chemical compositon were carried out using X-ray fluorescence (XRF) Nitton 3t, X-ray Diffraction (XRD) on the two different samples (the natural tropical clay and the one treated with Granite Sludge). The treatment with granite sludge will be done by 5, 10, 15 and 20% dry weight content in accordance with BS 1377 (1990) and BS 1924 (1990) respectively.

3. RESULTS AND DISCUSSION

The results of tests conducted on the Granite sludge is prsentd in Table 1. The Granite sludge was found to have high quantity of Silica (SiO_2 = 69.2 %), and some amount of Alumina (Al_2O_3= 16.0%). In addition, small amount of Ferric oxide, calcium oxide, potassium oxide, as well as traces of Titanium oxide and manganese oxide have also been found.

Also, the results of tests conducted on the Untreated and Treated Natural Clay, for identification and classification purposes, is presented on the same Table I. From the results, the soil is classified as CH and A-7-5 according to Unified Soil Classification System (USCS) and American Association for State Highway and Transportation Officials (AASHTO) respectively.

The level of Silica in the Granite sludge is 69.2 and 16.034% for the Alumina, which indicate it's a rich source of Silica when compare with Sample E which is the Untreated clay. The untreated clay has lower Alumina and will definitely affect the stability. This indicates that the geotechnical properties the falls below the standards, recommended for most civil engineering construction works, especially highway (Osinubi and Medubi, 1997), and therefore need stabilization.

When the clay is treated in 5, 10, 15 and 20 % (D, C, B and A) with the granite sludge, the X-ray Fluorescence indicated that they became richer in Silica and Alumina which is a sign of strength stability. From the Table 1, it can be seen that the level of Silica improved from D to A as the percentage of granite in the samples are increase gradually. Also the iron oxide content in the untreated sample E was very low which will definitely affect the strength, but with the augmentation in percentage, there was improvement in the iron oxide in the treated samples.

TABLE 1: Oxide Composition of the Untreated Clay Sample, Treated Sample and Granite Waste

Element	A 20%	B 15%	C 10%	D 5%	E 0%	Granite
Al_2O_3(%)	18.1254	17.7243	19.1000	18.1254	14.9781	16.0337

SiO_2(%)	52.0788	50.0787	44.0755	42.0788	40.0844	69.2034
P_2O_5(%)	0.8188	0.9019	0.8257	0.8188	0.00	0.00
SO_3(%)	0.9437	1.0517	0.9567	0.9437	0.00	0.00
K_20(%)	0.1936	0.2136	0.1936	0.1936	0.1222	1.8265
TiO_2(%)	0.1793	0.1747	0.1793	0.1793	0.1705	0.1142
MnO(%)	0.0249	0.0311	0.0249	0.0249	0.0419	0.0061
Fe_2O_3(%)	5.8530	6.0000	5.8530	5.8530	4.9257	2.0936
Nb_2O_5(%)	0.0135	0.0136	0.0135	0.0135	0.0128	0.0124
Ag_2O(%)	0.0091	0.0089	0.0091	0.0091	0.0035	0.0044
CdO(%)	0.0368	0.0363	0.0368	0.0368	0.0128	0.0012
MoO_3(%)	0.00	0.00	0.00	0.00	0.0012	0.0031
Sb_2O_5(%)	0.00	0.00	0.00	0.00	0.00	0.0067
PbO(%)	0.00	0.00	0.00	0.00	0.00	0.0023
SrO(%)	0.00	0.00	0.00	0.00	0.00	0.0475
CaO(%)	0.00	0.00	0.00	0.00	0.00	1.3087

Manganese Oxide was found in traces in the clay sample which increases the organic content of soil and made them useful for farming. For Geotechnical activities, Manganese oxide is expected to be very low or totally absent from the soil sample since organic matter is a disadvantage to any construction work. Organic content which goes beyond 10 % is said to be very high for construction work. The MnO was a bit higher in the untreated clay. When the treatment was done, there was reduction in the level of the MnO which lead to better strength and stability. There are some elements which are found in the granite sample, but for the fact that the blending with the clay was not up to 30%, this oxide never find their effect on the clay as such the clay was not reduced in strength with their presence in trace level.

The mineralogical analysis of the granite sludge used in this study was also performed using an x–ray diffract meter and Cu–ka radiation. Figure 1 shows the x–ray diffraction pattern of the granite sludge. The mineralogical content present in granite sludge obtained through x–ray diffraction indicates the presence of Oligoclase [(Na,Ca)$Al_{1-2}Si_{3-2}O_8$], Microcline [$KAlSi_3O_8$] and Melilite [$(Ca,Na)_2(Al,Mg,Fe^{2+})[(Al,Si)SiO_7]$]. This matches with the chemical composition obtained through analytically obtained results as reported in the figure 1 below.

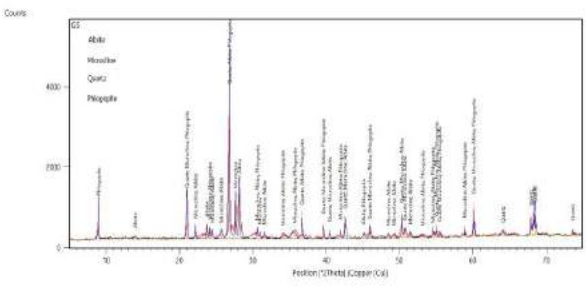

Figure 1: X–ray diffraction pattern of the granite sludge.

From the x-ray diffraction analyses, the untreated clay E was found to be made up of Quartz, Kaolione and Palygorskite. Palygorskite is a MagnesiumAluminium phyllosilicate with the formular MgAlSiO10mthat occur in clay. It's a fibrous clay and are different from other clay due to their tetrahedral sheet which divides into ribbons by inversion. The XRD showed that transcrystallization occur at the matrix interphase. This fibrous Clay has disadvantages for construction work especially when it involves road construction for heavy duty vehicle. If such clay is used, there won't be good strength stability and the road will not last. Thus led to the idea of making a blend with the use of sludge from the quarry which is a waste will be made to wealth.

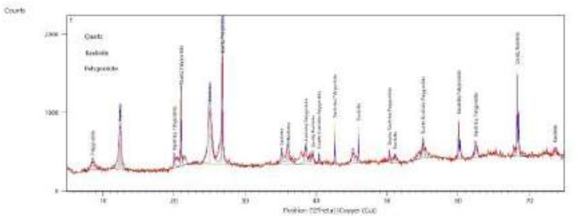

Figure 2: X–ray diffraction pattern of the Sample E Untreated Clay.

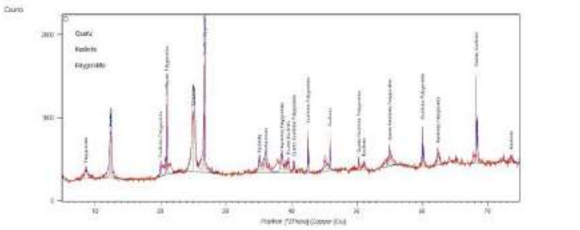

Figure 3: X–ray diffraction pattern of the Sample D Treated Clay with granite sludge.

Also, sample D which contain 5% of the granite sludge also showed the same parttern with the untreated clay. From the x-ray diffraction analyses, just like the untreated clay, the 5% treated clay contains Quartz, Kaoline and Palygorskite. The palygorskite is a MagnesiumAluminium phyllosilicate isn't as fibrous as the untreated due to the treatment with the granite sludge. The Palygorskite has drastically reduced due to the treatement with the granite sludge as such, it showed that the use of the granite sludge is working to stabilize the clay and reduce orcompletely eliminate the fibrous clay which will have effect on construction especially on highway construction where heavy duty vehicles that weigh tons and carries load which weighs hundreds of tons are plying.

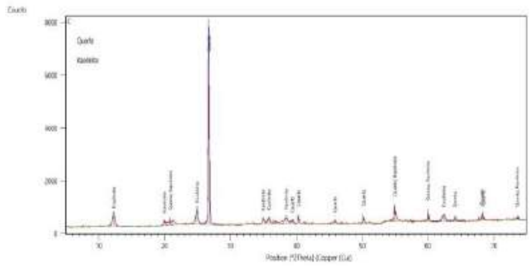

Figure 4: X–ray diffraction pattern of the Sample C Treated Clay with granite sludge.

As for the sample C, it's the 10 % treated clay with the granite sludge. The more the increment, the more the stability seen in the sample. Here the Palygorskite was not part of the compounds found in the clay anymore, but rather, Quartz and Kaolin. The strength will be found to increase the more for the fact that there's no more fibrous clay present in the clay anymore.

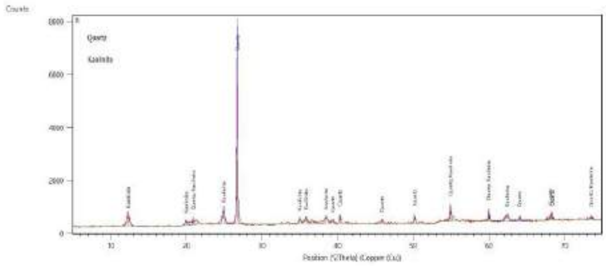

Figure 5: X–ray diffraction pattern of the Sample B Treated Clay with granite sludge.

On sample B, which is 15 % of the granite, there was a moderately high strength stability of the clay with no trace of Palygorskite found, but Quartz and Kaolinite. This showed that this clay will be good for Engineering construction.

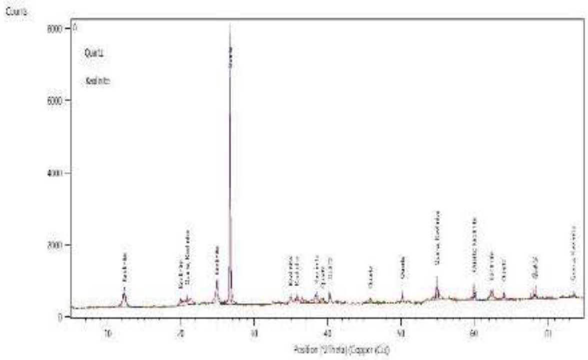

Figure 6: X–ray diffraction pattern of the Sample B Treated Clay with granite sludge.

The x–ray diffraction meter for the mineralogical analysis of the Sample A - granite sludge treated sample also performed. Figure 6 shows the x–ray diffraction pattern of the 20 % granite sludge treated Clay sample. The mineralogical content present in granite sludge obtained through x–ray diffraction indicates the presence of Quartz and Kaolinite with no trace of Palygorskite. This matches with the chemical composition obtained through the X-ray fluorescence. The strength stability here improves appreciably.

CONCLUSION

- From the research carried out and analyzed, the following conclusions were reached;
- Granite sludge is not a waste, but can be put into use as waste to wealth.
- Based on the AASHTO classification, the untreated clay is rated as a soft fibrous clay and thus, improvement must be made on it before it can be use for any civil work or any engineering purpose.
- Granite is a good stabilization agents for a fibrous clay and as a result, will lead to a cheaper and easy way to enrich the clay for better use.

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